622 Clauser Drive, Milpitas, CA 95035 (US). **ERICK-SON, Mark, A.** [US/US]; 421 35th Street, Sacramento, CA 95816 (US). **KANELLAKOPOULOS, Ioannis** [GR/US]; 10152 Firwood Drive, Cupertino, CA 95014 (US).
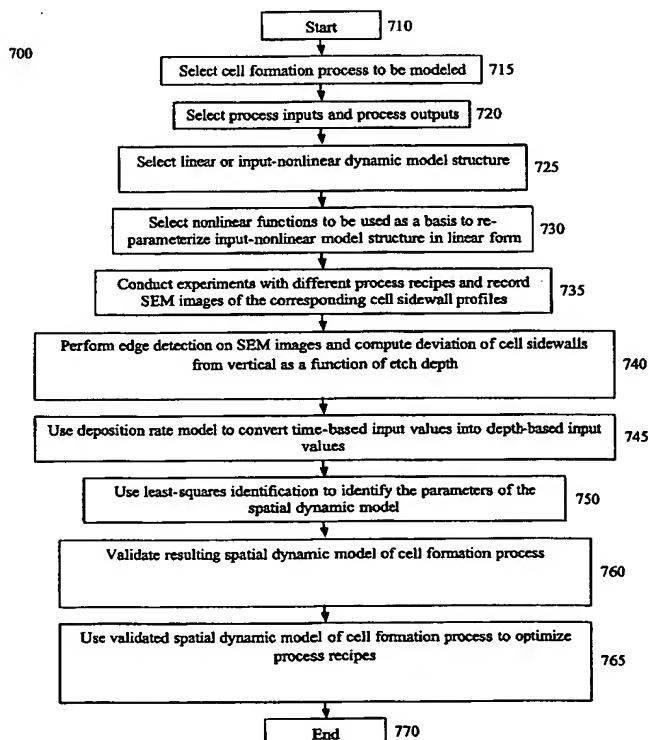
(74) Agent: **DUTTA, Sanjeet, K.**; 12400 Wilshire Boulevard, Seventh Floor, Los Angeles, CA 90025-1030 (US).

[Continued on next page]

(54) Title: METHOD AND SYSTEM FOR DYNAMIC MODELING AND RECIPE OPTIMIZATION OF SEMICONDUCTOR ETCH PROCESSES

(57) Abstract: A method and system are disclosed for creating dynamic models (Fig. 7:760) of etch processes in semiconductor manufacturing. In one embodiment, a method comprises modeling an etch process used in semiconductor manufacturing to generate a dynamic process model. The dynamic process model is used to determine input values (Fig. 7:720) that result in a desired output value. A process recipe (Fig. 7:765) is optimized for the etch process with the input values.

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AMENDED CLAIMS

[Received by the International Bureau on 24 November 2003 (24.11.2003);
original claims 8-13 replaced by amended claims 8-13, new claims 14-39
added, other claims unchanged
(6 pages)]

1. A method, comprising:

modeling an etch process used in semiconductor manufacturing to generate a dynamic process model;

using the dynamic process model to determine input parameters that meet a desired output parameter; and

optimizing a process recipe for the etch process with the input parameters.

2. The method of claim 1, wherein the etch process is a cell formation process.

3. The method of claim 1, wherein the dynamic process model is a linear ARX model with input nonlinearities.

4. The method of claim 1 wherein the optimized process recipe improves cell sidewall profiles.

5. The method of claim 4, wherein the optimized process recipe incorporates a maximum allowable number of recipe steps as an explicit process constraint.

6. The method of claim 4, wherein the optimized process recipe incorporates a maximum allowable input value as an explicit process constraint.

7. The method of claim 4, wherein the optimized process recipe incorporates a minimum allowable input value as an explicit process constraint.

8. The method of claim 1, wherein modeling an etch process, comprises:
using a non-linear model structure;
paramaterizing one or more memoryless non-linear functions associated with the non-linear model structure;
deriving a linear model from the non-linear model structure;

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identifying a bias value for one or more input parameters and one or more output parameters;

generating a dynamic spatial model of the one or more output parameters, wherein the one or more input parameters in a time domain relate to the one or more output parameters in a spatial domain;

predicting one or more future output parameters when one or more test input parameters are provided to the linear model; and

optimizing the one or more output parameters using the linear model.

9. The method of claim 8, wherein the dynamic spatial model is a deposition rate model.

10. The method of claim 8, wherein the one or more input parameters include:

one or more dopant gas flows including TriEthyl Borate, TriEthyl PhOsphate, and TetraEthyl OrthoSilicate; and

one or more plasma etch inputs including pressure, power, and gas flows.

11. The method of claim 8, wherein the one or more output parameters include one or more chemical vapor deposition outputs including Secondary Ion Mass Spectrometry dopant profiles before and after reflow, Fourier Transform Infrared Spectroscopy aggregate dopant profiles, plasma etch outputs, and wet clean outputs including electrical measurements, critical dimension measurements, Scanning Electron Microscopy cross-section sidewall profiles before and after wet etch in both X and Y directions.

12. The method of claim 1, further comprising manufacturing a semiconductor wafer with cell profile deviations less than 100 angstroms.

13. The method of claim 8, wherein the non-linear model structure is an INARX model, wherein the memoryless non-linear functions capture dynamic etch process behaviors.

14. A system, comprising:

means for modeling an etch process used in semiconductor manufacturing to generate a dynamic process model;

means for using the dynamic process model to determine input parameters that meet a desired output parameter; and

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means for optimizing a process recipe for the etch process with the input parameters.

15. The system of claim 14, wherein the etch process is a cell formation process.

16. The system of claim 14, wherein the dynamic process model is a linear ARX model with input nonlinearities.

17. The system of claim 14, wherein the optimized process recipe improves cell sidewall profiles.

18. The system of claim 17, wherein the optimized process recipe incorporates a maximum allowable number of recipe steps as an explicit process constraint.

19. The system of claim 17, wherein the optimized process recipe incorporates a maximum allowable input value as an explicit process constraint.

20. The system of claim 17, wherein the optimized process recipe incorporates a minimum allowable input value as an explicit process constraint.

21. The system of claim 14, wherein modeling an etch process, comprises:

means for using a non-linear model structure;

means for paramaterizing one or more memoryless non-linear functions associated with the non-linear model structure;

means for deriving a linear model from the non-linear model structure;

means for identifying a bias value for one or more input parameters and one or more output parameters;

means for generating a dynamic spatial model of the one or more output parameters, wherein the one or more input parameters in a time domain relate to the one or more output parameters in a spatial domain;

means for predicting one or more future output parameters when one or more test input parameters are provided to the linear model; and

means for optimizing the one or more output parameters using the linear model.

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22. The system of claim 21, wherein the dynamic spatial model is a deposition rate model.

23. The system of claim 21, wherein the one or more input parameters include:

    one or more dopant gas flows including TriEthyl Borate, TriEthyl PhOsphate, and TetraEthyl OrthoSilicate; and

    one or more plasma etch inputs including pressure, power, and gas flows.

24. The system of claim 21, wherein the one or more output parameters include one or more chemical vapor deposition outputs including Secondary Ion Mass Spectrometry dopant profiles before and after reflow, Fourier Transform Infrared Spectroscopy aggregate dopant profiles, plasma etch outputs, and wet clean outputs, wherein the wet clean outputs include electrical measurements, critical dimension measurements, and Scanning Electron Microscopy cross-section sidewall profiles before and after wet etch in both X and Y directions.

25. The system of claim 14, further comprising means for manufacturing a semiconductor wafer with cell profile deviations less than 100 angstroms.

26. The system of claim 21, wherein the non-linear model structure is an INARX model, wherein the memoryless non-linear functions capture dynamic etch process behaviors.

27. A computer readable medium, having stored thereon computer-readable instructions, which when executed in a computer system, cause the computer system to perform:

    modeling an etch process used in semiconductor manufacturing to generate a dynamic process model;

    using the dynamic process model to determine input parameters that meet a desired output parameter; and

    optimizing a process recipe for the etch process with the input parameters.

28. The computer-readable medium of claim 27, wherein the etch process is a cell formation process.

29. The computer-readable medium of claim 27, wherein the dynamic process model is a linear ARX model with input nonlinearities.

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30. The computer-readable medium of claim 27, wherein the optimized process recipe improves cell sidewall profiles.

31. The computer-readable medium of claim 30, wherein the optimized process recipe incorporates a maximum allowable number of recipe steps as an explicit process constraint.

32. The computer-readable medium of claim 30, wherein the optimized process recipe incorporates a maximum allowable input value as an explicit process constraint.

33. The computer-readable medium of claim 30, wherein the optimized process recipe incorporates a minimum allowable input value as an explicit process constraint.

34. The computer-readable medium of claim 27, further having stored thereon computer-readable instructions, which when executed in the computer system when modeling an etch process, cause the computer system to perform:

using a non-linear model structure;

paramaterizing one or more memoryless non-linear functions associated with the non-linear model structure;

deriving a linear model from the non-linear model structure;

identifying a bias value for one or more input parameters and one or more output parameters;

generating a dynamic spatial model of the one or more output parameters, wherein the one or more input parameters in a time domain relate to the one or more output parameters in a spatial domain;

predicting one or more future output parameters when one or more test input parameters are provided to the linear model; and

optimizing the one or more output parameters using the linear model.

35. The computer-readable medium of claim 34, wherein the dynamic spatial model is a deposition rate model.

36. The computer-readable medium of claim 34, wherein the one or more input parameters include:

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one or more dopant gas flows including TriEthyl Borate, TriEthyl PhOsphate, and TetraEthyl OrthoSilicate; and

one or more plasma etch inputs including pressure, power, and gas flows.

37. The computer-readable medium of claim 34, wherein the one or more output parameters include one or more chemical vapor deposition outputs including Secondary Ion Mass Spectrometry dopant profiles before and after reflow, Fourier Transform Infrared Spectroscopy aggregate dopant profiles, plasma etch outputs, and wet clean outputs including electrical measurements, critical dimension measurements, Scanning Electron Microscopy cross-section sidewall profiles before and after wet etch in both X and Y directions.

38. The computer-readable medium of claim 27, further having stored thereon computer-readable instructions, which when executed in the computer system, cause the computer system to perform manufacturing a semiconductor wafer with cell profile deviations less than 100 angstroms.

39. The computer-readable medium of claim 30, wherein the non-linear model structure is an INARX model, wherein the memoryless non-linear functions capture dynamic etch process behaviors.

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER

IPC(7)   :   G06F 9/45, G06F 17/50, H01L 21/3205, H01L 21/4763, G06F 19/00

US CL   :   716/5, 716/19, 438/14, 438/595, 700/121

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 716/5, 716/19, 438/689, 438/690, 700/121

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DIALOG, CAS ONLINE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6,133,132 A (TOPRAC et al.) 17 October 2000 (17.10.2000), column 3, line 7 to column 5, line 39.	1-13

☐ Further documents are listed in the continuation of Box C.   ☐ See patent family annex.

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"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier application or patent published on or after the international filing date		
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"O"	document referring to an oral disclosure, use, exhibition or other means		
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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA/US	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450	Mathew Smith Telephone No. (571) 272-1907
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